Solar Eclipse Brings AOP to the Residential Pool

SOLAR ECLIPSE

Ozone + Germicidal UV System - Advanced Oxidation Process (AOP) for Residential Pools

Overview

DEL Ozone introduces the first compact high technology Advanced Oxidation Process (AOP) system for residential pools. This innovative advanced sanitation system is a significant improvement over all previous approaches to residential pool sanitation.

The defining characteristic of AOP systems is the production of hydroxyl free radicals, the most powerful oxidizer available to safely disinfect water for human uses. The Solar Eclipse uses DEL's proprietary **Plasma Gap Ozone Technology** (patent pending) combined with high output, low-pressure germicidal UV lamps to make a potent yet economical AOP system small enough for residential pools.

The Solar Eclipse provides the benefits of both technologies plus the Advanced Oxidation Process for optimal water clarity and increased removal of contaminants in pool water. This innovative advanced sanitation system creates a synergy that injects higher disinfection potential into the pool water than the ozone and UV components can do independently.

AOP has been evolving since the 1980s, primarily for highly effective tertiary wastewater treatment. These very large-scale systems have been referred to as the wastewater treatment technology for the 21st century. Though the scale of wastewater AOP vs. DEL residential pool AOP is vastly different, the chemistry is the same. In both applications, the water is more effectively disinfected than by either ozone or UV alone, and certainly far more than chlorine.

About AOP

Advanced Oxidation Process refers to a variety of chemical treatments that can sanitize and disinfect water by oxidizing organic and inorganic contaminants. The concept is similar to the use of ozone for disinfection, but AOPs go beyond standard treatment methods because they produce hydroxyl free radicals (•OH).

Hydroxyl free radicals have a higher oxidation potential than any other substance, with the exception of elemental fluorine.[1] In AOP systems, the highly unstable hydroxyl free radicals react with dissolved waterborne contaminants in a series of strong oxidation reactions. This process happens almost instantaneously.

AOP systems are synergistic in the sense that they multiply the power of the precursor oxidants (like ozone) to yield more disinfection potential than the sum of the inputs taken separately.

DEL ozone™

There are two main reasons AOP systems are so desirable:

1. **AOP is highly effective:** AOP processes can *fully* oxidize organic contaminants of ALL kinds, including microorganisms, human waste, dangerous chemicals like pharmaceutical waste and petrochemicals, fungus, algae, pesticides and other toxic elements. They also oxidize non-organic materials, such as dissolved metals (iron, manganese, etc.) found in potable water, enabling their removal by filtration.
2. **AOP is environmentally benign:** The byproducts of AOP systems are clean enough for re-use. Even beginning with sewage waste, which is infinitely more contaminated than swimming pool water, these systems can eventually result in water pure enough to recycle. Byproducts may include water and carbon dioxide.

These two benefits are the same ones brought to the residential pool sanitation program by DEL Ozone's miniaturized AOP system.

The breakthrough Solar Eclipse builds on the capabilities of ozone and germicidal UV technologies. Taken separately, both of these approaches to sanitation are powerful, but taken together they produce a new, higher level of effectiveness. According to wastewater disinfection research published by the National Water Research Institute, ozone plus UV AOP is "more effective than O_3 or UV alone".[2]

In the Solar Eclipse, ozone and germicidal UV provide direct disinfection potential, but they also interact to create hydroxyl free radicals. The powerful hydroxyl free radicals produced in this small AOP system furnish the ultimate disinfection of swimming pool water by oxidation.

Powerful Precursors: Ozone and Germicidal UV

Pool professionals are familiar with both ozone and germicidal UV as components of pool sanitation systems. Generally, residential pool applications will use either one or the other alone for primary or supplemental sanitation. With both methods, chlorine dependence is reduced, microorganisms are inactivated or destroyed, and chloramines are broken down. Both of these methods are green, sustainable technologies.

The main difference between ozone and germicidal UV is that ozone uses oxidation to destroy a wide range of contaminants, but UV does not. UV uses light energy, especially at the 254-nanometer wavelength, to inactivate or break down microorganisms and organic disinfection byproducts like chloramines. Ozone works primarily at the point of injection, though a small residual may remain in the pool water body for a short time. UV is effective only as water passes through the radiation chamber, and only to the extent that the water is clear enough for the light waves to penetrate.

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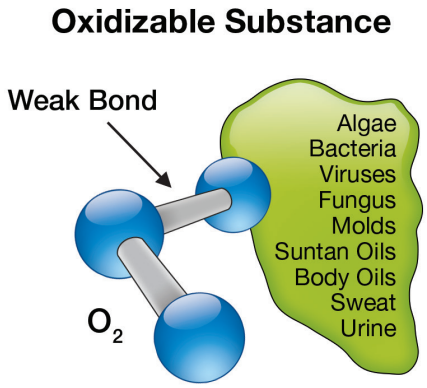
[1] *Treatment Technologies for Removal of Methyl Tertiary Butyl Ether (MBTE) from Drinking Water*, Second Edition, Gina Melin, Ed, National Water Research Institute, Feb 2000, p 113.
[2] *Treatment Technologies for Removal of Methyl Tertiary Butyl Ether (MBTE) from Drinking Water*, Second Edition, Gina Melin, Ed, National Water Research Institute, Feb 2000, p 122.

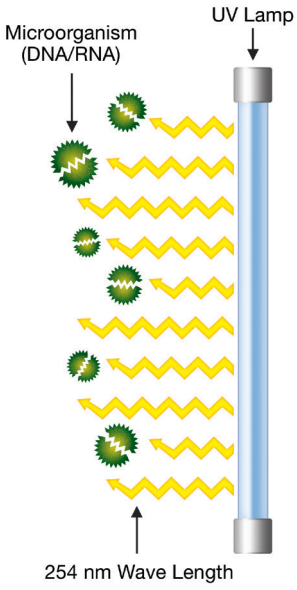
About Ozone Disinfection

Ozone (triatomic oxygen) is a molecular allotrope of oxygen, with three oxygen atoms (O_3, compared to the two atoms in atmospheric oxygen, O_2). It exists naturally in the gaseous state, usually generated either by solar radiation or by lightning (electrical energy – commonly called corona discharge) passing through air. DEL Ozone uses corona discharge technology to generate ozone because it is much more efficiently productive than alternatives. The most important chemical property of ozone is that the third atom is attached by a weak bond, which means that ozone is a strong oxidant. Ozone disinfection occurs through oxidation.

An oxidation reaction occurs when ozone comes into contact with an oxidizable substance. When ozone is dissolved in pool water (creating 'aqueous ozone'), it can oxidize a very wide class of organic and inorganic substances found in pools, including microorganisms (bacteria, viruses, spores, plankton, protozoa), disinfection byproducts like chloramines, chloramine precursors, algae, oils, sweat and urine. When the unstable ozone molecule encounters one of these substances, the third oxygen atom detaches and breaks down the substance. In effect, it destroys as it oxidizes.



Ozone gas for a swimming pool is manufactured by an ozone generator like the industry standard DEL Ozone Eclipse corona discharge ozonator. The most effective mass transfer method for dissolving ozone in pool water uses a partial vacuum created by a venturi injector to draw ozone into a turbulent water flow, effectively dissolving it. Disinfection occurs immediately in the return line, with only a small residual of ozone entering the pool where it will be consumed very quickly.



About Germicidal UV Disinfection

UV lamps produce light waves that disrupt or break down organic molecules. Low-pressure UV lamps produce a high proportion of light in the 'germicidal spectrum' of 250 to 280 nanometers, and they can be optimally calibrated to emit at the 253.7 nanometer wavelength (usually referred to as 254 nm). The DNA or RNA of microorganisms exposed to this light is disrupted, effectively killing the organism.

UV systems channel pool water through a chamber that is exposed to the UV light. The light is simply generated by the UV lamp powered by ordinary electrical current.

Ozone and UV for Pool Disinfection

The following table summarizes the important properties of ozone and germicidal UV for residential pool disinfection:

Property	Ozone	Germicidal UV
Application method	Ozone gas is dissolved in water	Water is passed through radiation chamber
Disinfection activation	Oxidation: Contaminants are reduced & neutralized through osmotic bursting	Disruption of organic cell mechanics, e.g., DNA or RNA
Regulatory status	EPA approved antimicrobial oxidizer, sanitizer and disinfectant	EPA approved for water sanitation
Antimicrobial	Yes, including Cryptosporidium	Yes, including Cryptosporidium
Fungicide	Yes	Yes
Algaecide	Yes	Yes
Destroys humic and fumic acids	Yes – byproducts of organic decomposition are oxidized	No – does not oxidize
Biofilm	Yes – when in contact	No – does not oxidize
Control chloramines	Yes, by oxidation of precursor organic materials (e.g., urine components) and by direct oxidation	Yes – breaks down chloramines molecules
Dissolved metal control	Yes, by oxidation	No – does not oxidize
Micro flocculent	Yes	No
Improves water clarity	Yes	No
Compatible with chlorine	Yes, in normal pH range	Partially – can consume some chlorine
Reduces chlorine demand	Yes, usually from 50 to 75%	Yes, 25 to 50%

Ozone + UV → AOP

The fundamental reason to combine ozone and germicidal UV in a single system is that the *UV light interacts with the ozone, and the resulting chemical reaction generates hydroxyl free radicals*. Since the hydroxyl free radicals have even more oxidation potential than ozone, the power of the whole system is increased. This is the synergy of the Advanced Oxidation Process.

The following table gives a comparison of the oxidation potential of oxidizers.

Comparative Oxidation Potential of Standard Oxidizers [3]		
Oxidizer	**Oxidation Potential (electron volts)**	**Oxidation Potential Relative to Chlorine**
Elemental Fluorine	3.06	2.25
Hydroxyl free radical	2.80	2.05
Oxygen (atomic)	2.42	1.78
Ozone (O_3)	2.08	1.52
Hydrogen Peroxide	1.78	1.30
Chlorine	1.36	1.00

A simplified description of the chemical reaction is:[4]

Dissolved ozone is exposed to UV light in the 254 nm wavelength.

The first reaction products are O_2 and the O atom. The O atom quickly reacts with H_2O to form two •OH free radicals

Simultaneously two •OH may combine to form H_2O_2, but in the presence of more O_3 (and more UV) the H_2O_2 quickly decomposes to produce more •OH free radicals

These two processes occur instantaneously in the UV chamber.

The hydroxyl free radicals instantly begin to oxidize organic and inorganic substances in the pool return line.

The Solar Eclipse AOP provides disinfection in three steps

1. Ozone directly oxidizes contaminants as it is injected into the return line. However, a portion of the ozone is still available when it enters the UV light chamber.
2. Germicidal UV continues the disinfection process by disrupting organic molecule DNA/RNA, but it also interacts with the remaining ozone to produce hydroxyl free radicals.
3. The hydroxyl free radicals complete the oxidation process. This very powerful oxidant is extremely short lived, but it instantly oxidizes contaminants in pool water.

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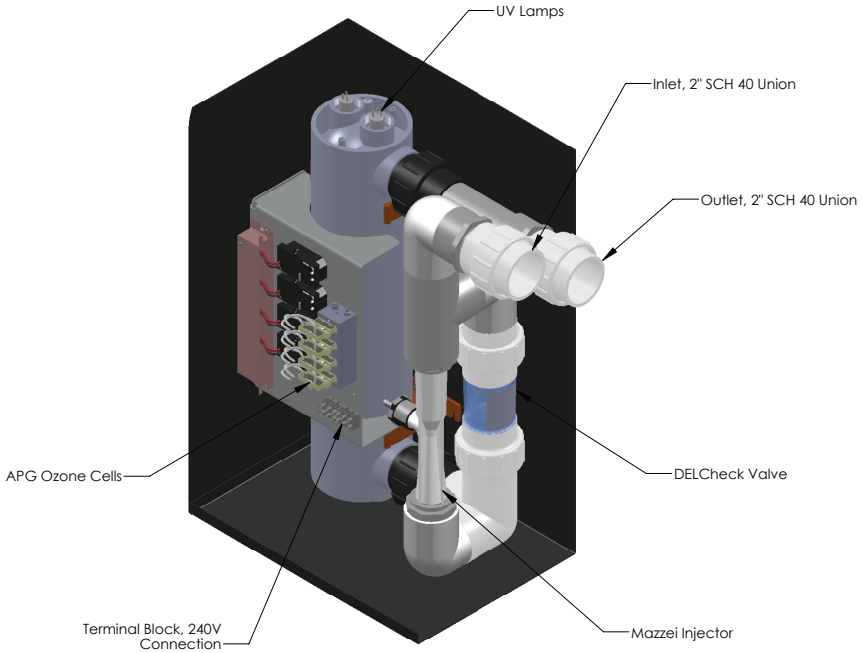
[3] *Taken from Understanding AOP,* Greg Reyneke, Water Conditioning & Purification, October 2012, p 14.
[4] *Advanced Oxidation Processes: Mechanistic Aspects,* C. von Sonntag, Water Science & Technology, 2008, pp 1015 – 1021. The article includes summary chemical reactions for a number of different AOP methods.

The multi-step oxidation/irradiation process destroys organic and inorganic contaminants in pool water, including pesticides, human organic wastes, chloramines and chloramine precursors, pharmaceutical pollutants, microorganisms like *Cryptosporidium parvum*, and oxidizes other non-organic materials like dissolved metals.

Solar Eclipse: AOP in a Residential Pool Package

AOP applications for wastewater treatment are obviously out of scale for pool applications, especially residential pools. However, DEL Ozone's small but effective technology permits manufacturing an AOP system that will fit compatibly with the mechanical and plumbing equipment of almost all residential pools. It is available in 240 volt configuration.



The Solar Eclipse residential pool sanitizer is built primarily from two components – the ozone generator and the UV lamp chamber – which are pre-plumbed and pre-wired. The system installs with simple inlet and outlet unions for water flow and one electrical connection.

The Advanced Plasma Gap (APG) Ozone Generator

First, the system includes DEL's proprietary (patent pending) Advanced Plasma Gap ozone corona discharge cells that deliver ozone via a venturi injector on the pool return line. This proven and familiar layout is important

because the Solar Eclipse AOP system depends on a steady supply of ozone to feed the oxidation chemical reaction. The consistent production of ozone and its efficient mass-transfer through the venturi injector into the water are critical to the success of the system.

The innovative APG is important to the success of the Solar Eclipse. Ozone delivery is almost constant across time, avoiding the typical slow deterioration in performance of some other ozone generators. The APG is a compact, solid-state design with low power consumption, yielding very high ozone generation efficiency measured as watts consumed per ozone unit generated per hour. Some advantages of the APG include:

- There are no metals exposed to ozone, and therefore no corrosion
- APG has an extremely long life
- It provides high reliability at low cost
- No internal tubing
- Water backflow will not damage it

The APG indicates a paradigm shift in pool and spa ozone generators.

Germicidal UV Lamps

The UV component includes two high output, low-pressure germicidal UV lamps that are installed downstream from the ozone system on the return line. These carefully calibrated lamps shine light into an irradiation chamber in the 254-nanometer wavelength, sometimes referred to as Ultraviolet C short wave. This wavelength is important because it disrupts the cellular DNA/RNA of microorganisms, but also because ozone is especially prone to absorbing UV 254, which triggers the breakdown of O_3 in the chemical chain reaction that produces hydroxyl free radicals.

The oxidation reaction is completed in the return line. Clean disinfected water returns to the pool.

Basic Installation Protocols

Every pool equipment layout is unique to some extent, but the components are quite standard. There is nothing about the Solar Eclipse that will require substantial changes in pool design or construction. Pool professionals who are proficient in installing existing ozone sanitation systems will be immediately familiar with the Solar Eclipse.

Like DEL ozonators before it, the Solar Eclipse is installed on the return line downstream of other pool equipment. The Solar Eclipse itself is designed to limit internally-generated backpressure (the UV chamber does not create substantial backpressure), but the effectiveness of the venturi ozone injector still relies on creating a pressure differential between water flow before and after the injector. The water flow through the Solar Eclipse should be unimpeded.

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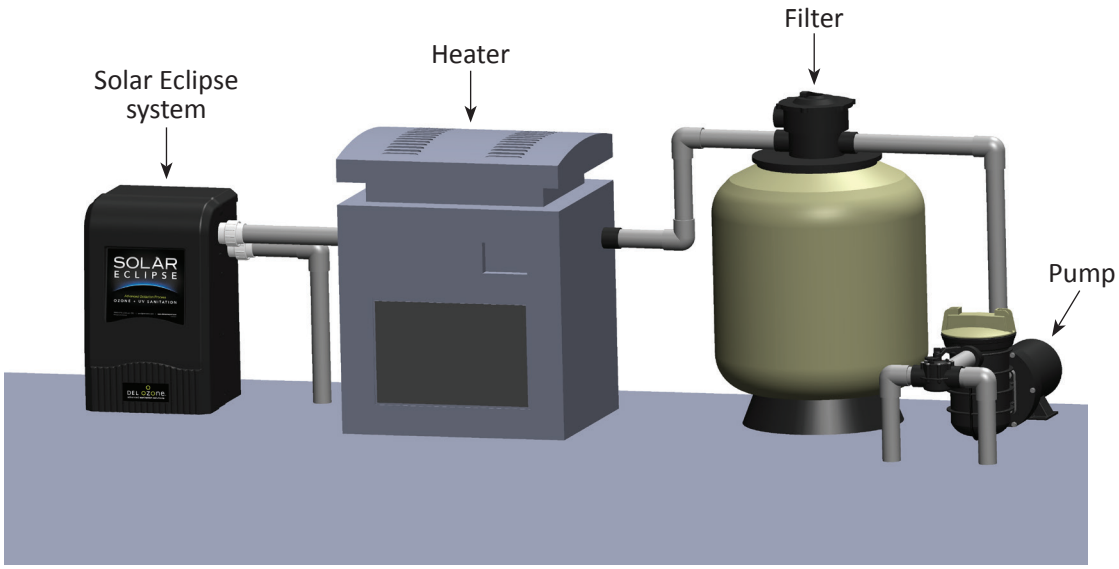

Modern variable speed pumps will work well with Solar Eclipse. The same calibrated spring-driven check valve in DEL's popular standard manifold automatically adjusts for large variations in water flow/water pressure.

The system can be tuned to work with in-floor cleaning systems by choosing water input and outflow points that provides a pressure differential to activate the venturi injector.

Residential Pool Sanitation in the 21st Century

The Solar Eclipse is an innovative, powerful and practical design. It will substantially alter and improve residential pool sanitation programs, with benefits that pool owners will appreciate immediately.

- Pool water disinfection will become more effective and more reliable, covering the broadest spectrum of contaminants of any system to date.
- With correct installation and operation, the system will allow the smallest chlorine residual of any safe sanitation method.
- Pool owners will be able to follow simplified sanitation programs, improving both water quality and quality of life.
- Pool professionals will find that the Solar Eclipse is easy to install using standard methods.
- Extremely energy efficient - Solar Eclipse uses approximately the same energy as a 100 watt light bulb.

A clean, easily-maintained pool improves owner satisfaction. Pool professionals benefit from that.

www.delozonepool.com

DEL ozone™

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